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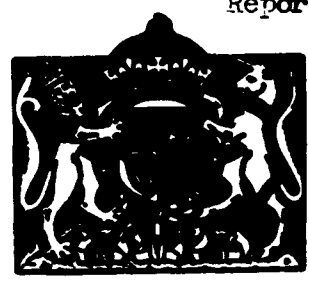
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MINISTRY OF SUPPLY

**AEROPLANE AND ARMAMENT
EXPERIMENTAL ESTABLISHMENT**

BOSCOMBE DOWN

GROUND POWER CHECKING OF HELICOPTER ENGINES

TESTS WITH A HOVERFLY 1

by

D.A. WILKINSON, D.L.C.

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29. AUG. 1952

AEROPLANE AND ARMAMENT EXPERIMENTAL ESTABLISHMENT
BOSCOMBE DOWN

Ground power checking of helicopter engines

Tests with a Hoverfly 1

by

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Summary

A preliminary investigation has been made on a Hoverfly 1 of the possibility of ground checking the power of helicopter engines. Tests have been made with both standard blades and blades fitted with attachments.

These tests confirm that power checks which involve tethering are unsatisfactory and indicate that power checks should be made under low lift conditions. Two methods of achieving this condition were investigated, one using lift spoilers at high pitch, and the other using drag plates at low pitch. The latter method proved to be the more satisfactory and appears to provide a practical solution, without undue handling problems, by which power variations of the order of 2% could be detected. This method may be suitable for use by qualified ground crew provided that precautions are taken to prevent the occurrence of dangerous blade motions.

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1. Introduction

Regular power checks are made on fixed wing aircraft by qualified ground crew who run the engine with the aircraft secured on the ground. In order to avoid excessive ground running at high power settings these checks may be made at the Reference Boost condition specified for each type of engine, and this condition may, for some types, be substantially less than the maximum obtainable. Nevertheless, checks are made at full power as dictated by the servicing schedule and on such other occasions as are thought necessary.

On helicopters, however, ground checks at full power have not been possible except by tethering since the aircraft would generally become airborne. Checks made in this way are not considered fully reliable because of uncertainty concerning wind and ground effects, and it has been generally agreed that a more controlled method of checking is required. It is desirable that the method evolved should be suitable for use by ground crew, who, at present, are not permitted to make full or even partial power checks on helicopters.

Various schemes for ground power checking have been suggested recently, and this Establishment was asked to make a preliminary investigation of the problem.

2. Range of investigation

The purpose of the investigation was to examine the principles of helicopter ground power checking rather than to develop a scheme practicable for general application. The power check, to be of most value, should be a measure of the performance of the engine and rotor combination and the employment of a relatively low Reference engine power may not provide a satisfactory check on the rotor drag characteristics. It has therefore been assumed for these tests that the checks should be made at nearly full power.

Tests have been made with a helicopter running at high engine power on the ground, under both high and low lift conditions. For the high lift condition the helicopter was operated in the normal state, but was prevented from leaving the ground by tethering and ballasting. For the low lift condition the power was absorbed either by increasing blade drag at low pitch by the use of drag attachments, or by destroying the lift at higher pitch with spoilers.

Some attention has been given to the effect of wind and other variable conditions upon the consistency of the results, and to the ease of operation of the schemes with reference to their possible use as a standard procedure for power checking.

The tests were of a restricted nature because the aircraft, a Hoverfly 1, was available only for a limited period.

3. Description of aircraft

The aircraft used for the tests was a standard Hoverfly 1, KK.990, fitted with a Warner Super-Scorab R-550-3 engine.

In general the aircraft was ballasted with 1000 lbs. of concrete slab disposed equally between the two lower main undercarriage braces; in one test the aircraft was not ballasted and at low weight to determine the order of lift developed.

For the tests with normal blades, and the first test with drag attachments, the aircraft was also tethered to four screw pickets, one to each main undercarriage and two to the tail oleo structure to prevent swing of the aircraft.

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In some of the tests the full range of throttle control was required at the minimum position of the pitch lever, and a modification was made to the throttle linkage; the maximum manifold pressure available at this setting was thereby increased from 17 in. Hg. to 27 ins. Hg. It was still necessary to increase the pitch slightly in order to obtain the maximum manifold pressure of 29 ins. Hg.

The relevant engine limitations for the Hoverfly 1 are as follows:

<u>Condition</u>	<u>Take-off</u>	<u>Normal Rated</u>
Engine R.P.M.	2475	2100
Manifold pressure ins. Hg.	29.0	28.5
B.H.P.	200	180

4. Details of blade attachments

4.1 Drag attachments. Various forms of drag attachment were considered, including plates of different shape fitted to the leading or trailing edges of the blade. It was decided that a rectangular plate fitted to the leading edge had many advantages, including ease of attachment and the destruction of lift over the section treated.

The target conditions selected were those of the Normal Rated Power quoted in § 3, giving 90% of the take-off power.

It was estimated that for a plate having its centre of pressure about 1 ft. inboard of the blade tip, an area of about 32 sq.ins. per blade would be required to absorb the power input. The arrangement adopted was a plate $1\frac{1}{2}$ " deep attached at right angles to the blade chord line and disposed equally about it. This was affixed to the leading edge by means of wood screws, and braced to the upper and lower surfaces.

The area of each plate was increased from the estimated value of 32 sq.ins. to 36 sq.ins. ($24" \times 1\frac{1}{2}"$) in order to enable the effect of different areas of plate to be determined by trimming the inboard ends of the plates.

Details of the drag plates are given in Fig. 1A and a photograph at the end of the report.

4.2 Lift spoilers. The purpose of the spoilers was to reduce the lift developed when using high pitch to absorb the engine power. The type of spoiler used was a simple blade attachment which produced turbulence over the upper surface of the blades at high angles of incidence, although a certain amount of lift was still developed by the undersurface.

It was estimated that if the outboard 3 ft. of each blade were treated in this manner the lift would be reduced to a sufficiently low value.

Details of the lift spoiler are shown in Fig. 1B and a photograph at the end of the report.

5. Tests made

5.1 General. During the tests the aircraft was headed into wind and the cyclic pitch and rudder controls held in a neutral position in order to reproduce comparable conditions in successive tests. For each set of blades runs were made at the lower pitch settings with the throttle linkage modified to give a wide range of control. The modification was then removed and runs were made at the higher pitch settings at which the normal linkage gave adequate throttle control.

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The pitch values were measured by the aircraft pitch indicator but it was not possible to calibrate this instrument before the aircraft left the Establishment. However, there was no backlash in the system and the various datum points could be reselected in a consistent manner.

5.2 Tests with normal blades. For these tests the aircraft was ballasted and tethered as in § 3. The blades were standard for the type of aircraft.

Runs were made at various pitch settings and at each setting the engine speeds resulting from a range of manifold pressures were noted.

It was intended that further runs should be made in a range of wind speeds, but shortage of time prevented this.

5.3 Tests with drag plates. Tests were made in winds of up to 13 knots, the procedure being as in § 5.1 above. For the first run the aircraft was both ballasted and tethered, but for subsequent tests in this series only ballasting was considered necessary.

Sets of data were obtained for pitch settings of 4° , 6° and 8° , and drag plates of 24 ins. 22 ins and 20 ins. span, the trimming being performed on the inboard end.

Tests were made to investigate the effect of control position by making runs with the rudder pedals central and fully displaced either to right or left. A rope was attached to the tail oleo structure in this case to control the tendency of the aircraft to swing. Tests were also made with small displacements of the cyclic pitch control about its neutral position. The engine speeds were noted in all cases.

One pilot repeated a test on several occasions, and three pilots and an engineering officer all repeated another run in order to provide an indication of the possible effects of personal techniques on the results.

5.4 Tests with the lift spoilers. One series of tests was made with lift spoilers attached to the outboard 3 ft. of each blade. Runs were made at 4° , 8° and 10° pitch, and full power was obtained in the latter case. The aircraft was neither ballasted nor tethered in order to obtain an indication of the effectiveness of the spoilers in reducing lift.

6. Results of tests

6.1 Tests with normal blades. The variation of engine speed with manifold pressure at various pitch settings is shown in Fig. 2A. It will be seen that at least 12° of pitch is necessary in order to approach the target conditions. At this pitch the aircraft was extremely lively, although no violent motion developed, and the blades were coned and flexed upward at the tip.

6.2 Tests with drag plates. In Fig. 2B the results with drag plates show that the power required to rotate the motor was considerably greater than without drag plates, and the target conditions were reached with a pitch of 8° . The manifold pressure of 27 in. Hg. in the 4° test was the maximum value attainable with the modified throttle linkage. In the 8° setting the normal linkage was adequate to reach 28.5 ins. Hg.

The curves of Fig. 3 show the effect of trimming the drag plates by stages of 2 ins. from the inboard end. It will be seen that the reduction in span of 2 ins. corresponds to an increase in engine speed of 60 - 70 R.P.M. at constant manifold pressure.

/The.....

The effect of varying the power to the tail rotor is shown in Fig.4. Full right rudder reduced the engine speed by about 30 R.P.M. from the value with the rudders central, whilst full left rudder caused a reduction of about 80 R.P.M. No difficulty was experienced in controlling the swing of the aircraft. The central rudder position was positively attained on this aircraft by aligning the four pedals of the two side-by-side pilot positions.

Some tests were made to determine the effect of wind on engine speed at constant pitch and manifold pressure. The results were insufficient to be conclusive but the effect appeared to be small for low lift conditions and of the order of - 20 R.P.M. for an increase in wind speed from 0 to 10 kts.

The results of the repetitive tests with one pilot indicate that set conditions may be attained with only a small variation of engine speed of the order of ± 10 R.P.M.

Table 1 gives the results obtained by several pilots and an engineering officer for similar conditions. Approximate corrections for atmospheric conditions have been applied to the 4° case, and it will be seen that differences from the corrected mean engine speed are as much as ± 30 R.P.M. Corrections have not been applied to the 8° case since this represents a higher lift condition with less certainty of the effect of wind.

Throughout the tests with drag plates the aircraft remained entirely manageable and firmly on the ground.

It was observed that the blades fitted with drag plates were not at any time flexed upward at the tip; this suggests that most of the lift on the outboard sections of the blade had been destroyed by the plates.

6.3 Tests with lift spoilers. The results obtained with lift spoilers for 4° , 8° and 10° blade pitch settings are shown in Fig. 2C. It will be seen that at 10° pitch the take-off power conditions were nearly reached, and at this pitch a marked lateral oscillation occurred at power above 24 ins. Hg.

During these tests the aircraft was neither ballasted nor tethered and it was found possible to hover the aircraft a few inches from the ground at high pitch.

7. Discussion

The tests with the helicopter tethered confirm that this method of power checking is not entirely satisfactory because of the disturbed motions of the blades and aircraft, and the possible occurrence of ground resonance.

The results of these tests show that the pitch required to absorb 80% - 90% of take-off power with unmodified blades produces sufficient lift for the aircraft to become uncomfortable to handle when ballasted and tethered. This difficulty would probably increase with higher powered helicopters of similar configuration. In addition, the effect of wind upon the consistency of the engine speed may be considerable where high lift is generated because of the variation of ground effect. With multi-engined helicopters there may be greater possibilities of power checking without special blade attachments since one engine only may be used to drive the rotor system.

The tests with the drag plates, on the other hand, have shown that their use enables high engine powers to be absorbed at low pitch and without serious handling problems.

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The attachment of drag plates to existing helicopters as a possible standard procedure presents certain problems, but on future helicopters most of these difficulties would not arise if suitable provisions were made at the design stage. It may ultimately be possible to incorporate the drag plate in the structure of the blade as, say, an adjustable leading edge boot.

The degree of accuracy attainable with the drag plates is important in assessing the practicability of the scheme. The discrepancies of ± 30 r.p.m. in corrected engine speed observed in tests by successive operators (§ 6.2 and Table 1) represent at constant manifold pressure an apparent variation in engine power of approximately $\pm 1\%$. Differences of this kind might be minimised by evolving a drill for making the power check, possibly utilising simple control position indicators, and with such precautions it is considered that actual power differences of 2% or less might be consistently detected. Corrections for the effects of variable atmospheric conditions could be read from charts prepared in similar manner to those used in fixed wing practice. Torquemeters are a refinement by which the power developed may be measured more directly, but they do not in themselves solve the basic problem of ground power checking.

The lift spoilers were not as effective as had been anticipated, and because of the difficulties of manufacture and positioning, coupled with the success of the drag plate system, the development of the lift spoilers was not continued.

The drag plate method appears to be very promising as a standard procedure for power checking, but the possibility of its use by ground crew needs more consideration than can be given in this report. There is, however, the possibility that personnel not trained as pilots may initiate dangerous blade motions through inexperienced control movements, and the need for restriction of cyclic and collective pitch controls should be considered.

8. Conclusions

The tests with the helicopter tethered show that power checks made in this way are unsatisfactory both from the handling aspect and because uncertainty of the effect of wind makes the accuracy unreliable.

A possible alternative method is to use spoilers to destroy the lift developed at high pitch settings, but those used during these tests proved to be unsatisfactory in this respect.

Successful results have been obtained with drag plates affixed to the leading edge of the blades in order to absorb high engine power at low pitch. No handling problems were experienced and power variations of the order of 2% should be detected by this method. The possible use of this type of power check by ground crew must receive further consideration, with particular reference to the restriction of control movements as a precaution against possible dangerous blade motions.

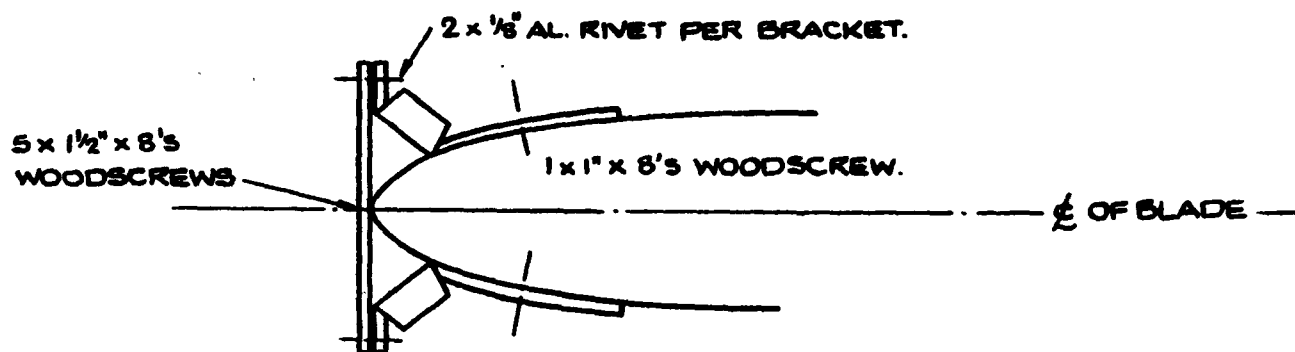
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Table 1

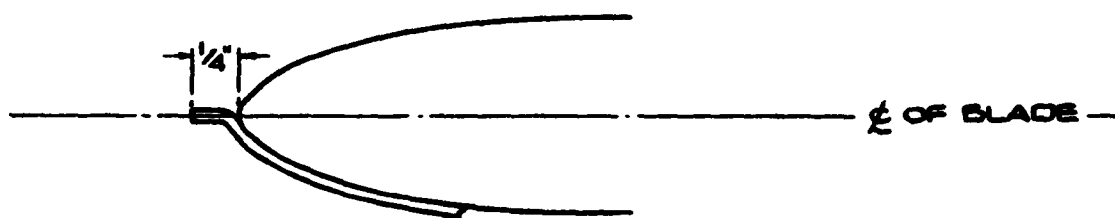
Results of tests repeated by different operators
20 in. span drag plates

Pilot A.				Pilot B.				Pilot C.				Engineer			
Wind Speed Air Temp. Water Vapour Pressure 18 mbs				13 kts. 18°C 12 mbs.				13 kts. 18°C 12 mbs.				4 kts. 17°C 11 mbs.			
40 Pitch				40 Pitch				40 Pitch				40 Pitch			
Boost	R.P.M.	Boost	R.P.M.	Boost	R.P.M.	Boost	R.P.M.	Boost	R.P.M.	Boost	R.P.M.	Boost	R.P.M.	Boost	R.P.M.
16"	1600	16"	1400	16"	1620	16"	1410	16"	1600	16"	1410	16"	1680	16"	1400
22"	2040	22"	1900	22"	2040	22"	1830	22"	2000	22"	1780	22"	2080	22"	1870
27"	2210	27"	2110	27"	2220	27"	2100	27"	2220	27"	2030	27"	2280	27"	2100
								Results for 4° pitch corrected approximately to wind speed 13 kts, air temp. 18°C and water vapour pressure 12 m.b.s.							



DRAG PLATE: 24" x 1 1/2" x 16 ga DURAL.
BRACKETS: 1" WIDE. 16 ga AL. CENTRE PORTION FLANGED.
8 PER PLATE.

FIG.1 (A) ATTACHMENT OF DRAG PLATES.



SPOILER: 36" x 4" x 18 ga AL.

FIG.1 (B). FORM OF LIFT SPOILER USED.

DETAILS OF BLADE ATTACHMENTS.

FIG. 2.

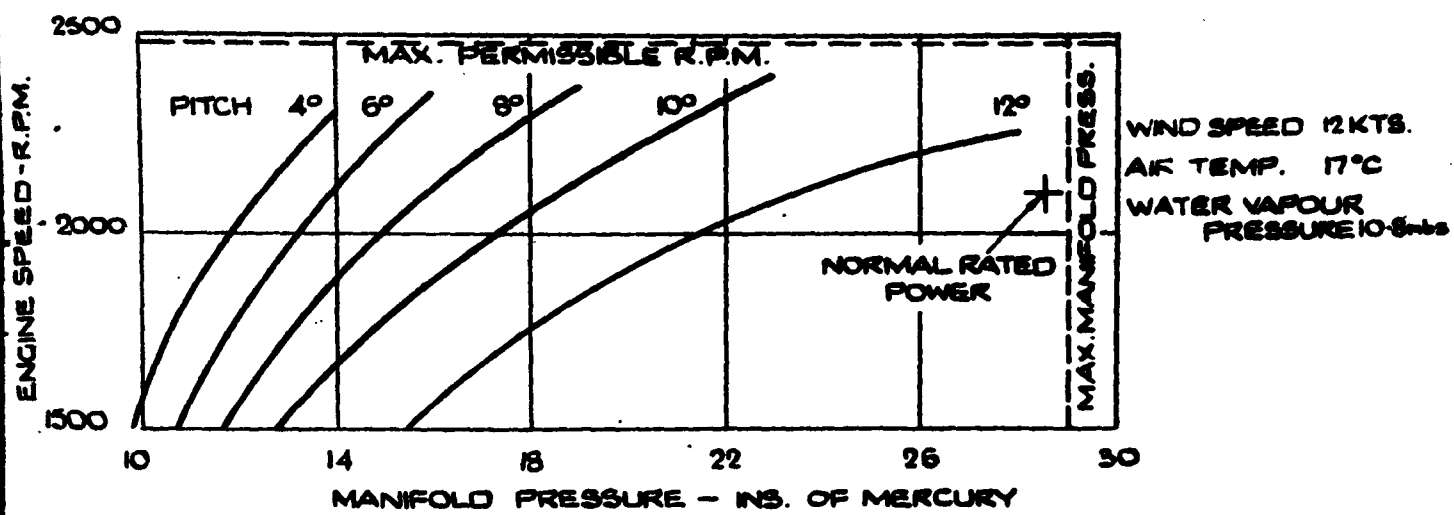


FIG. 2 A. USING NORMAL BLADES.

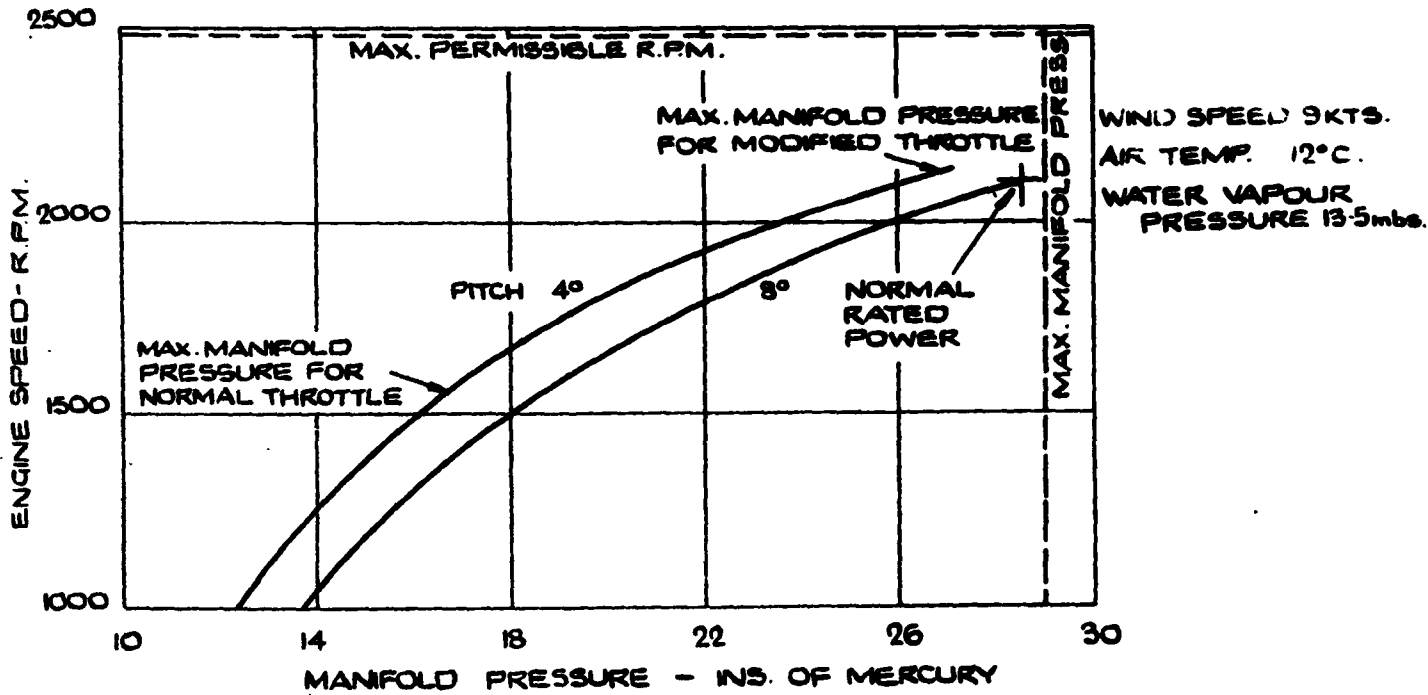


FIG. 2 B. USING DRAG PLATES.

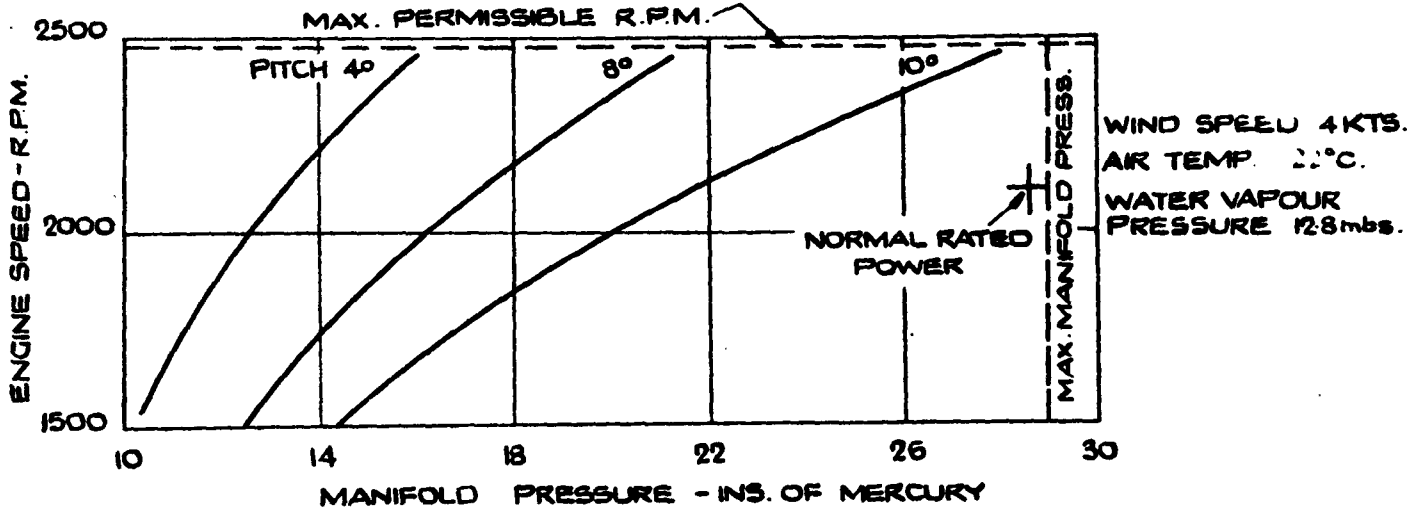


FIG. 2 C. USING LIFT SPOILERS

THE VARIATION OF ENGINE SPEED WITH MANIFOLD PRESSURE AT CONSTANT PITCH SETTINGS.

FIG^s 3 & 4.

LENGTH OF PLATES	A	B	C
WIND SPEED - KTS.	24"	22"	20"
AIR TEMP. °C.	6	4	0-2
WATER VAPOUR PRESSURE mbs.	15	13	19
	12	12.8	18

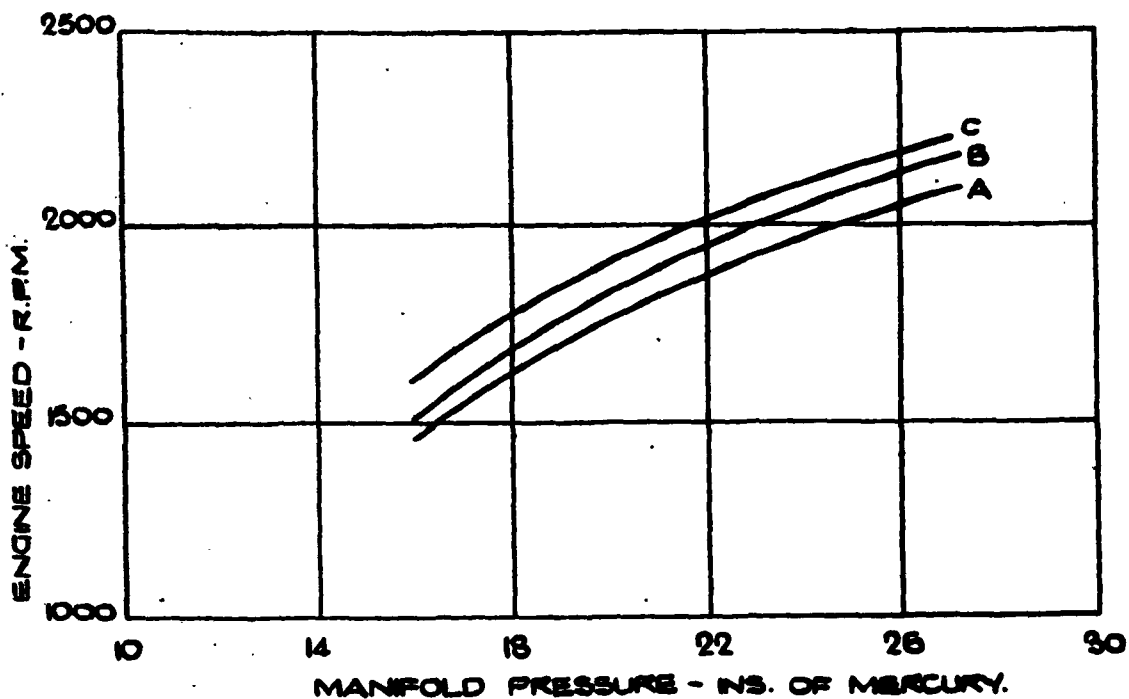


FIG. 3. THE EFFECT OF REDUCED DRAG PLATE SPAN ON ENGINE SPEED.

DRAG PLATES 20" LONG.
○ RUDDER PEDALS CENTRAL.
+ FULL RIGHT RUDDER.
× FULL LEFT RUDDER.

WIND SPEED 0-2 KTS.
AIR TEMP. 19°C.
WATER VAPOUR PRESSURE 18 mbs.

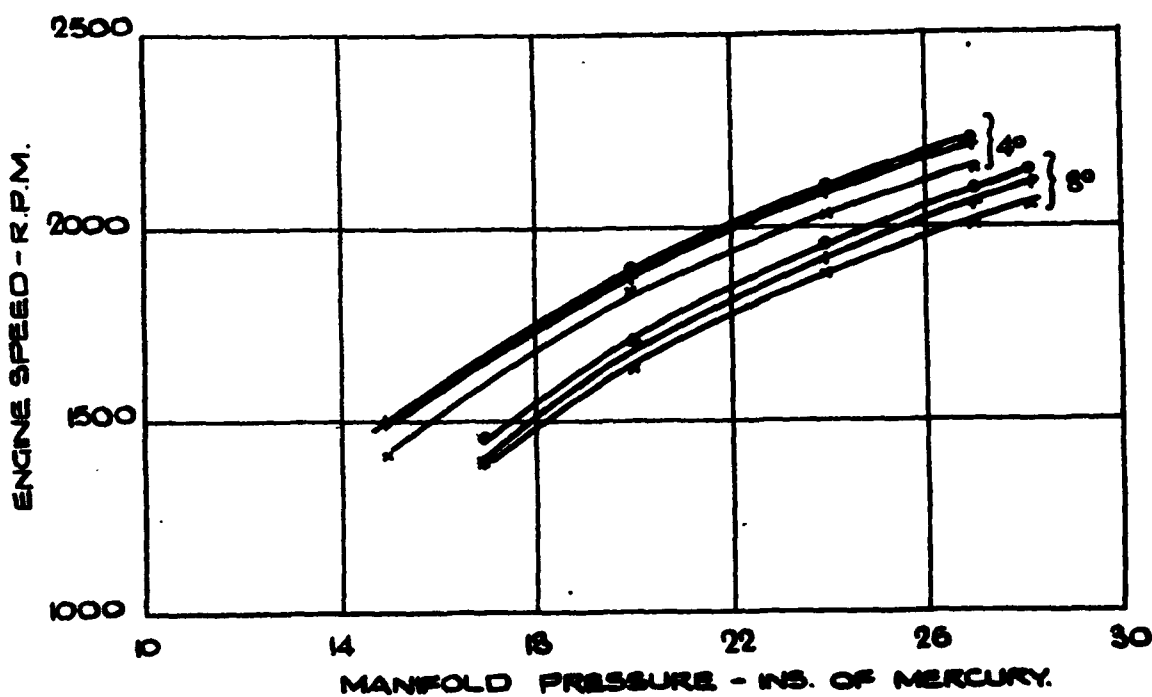
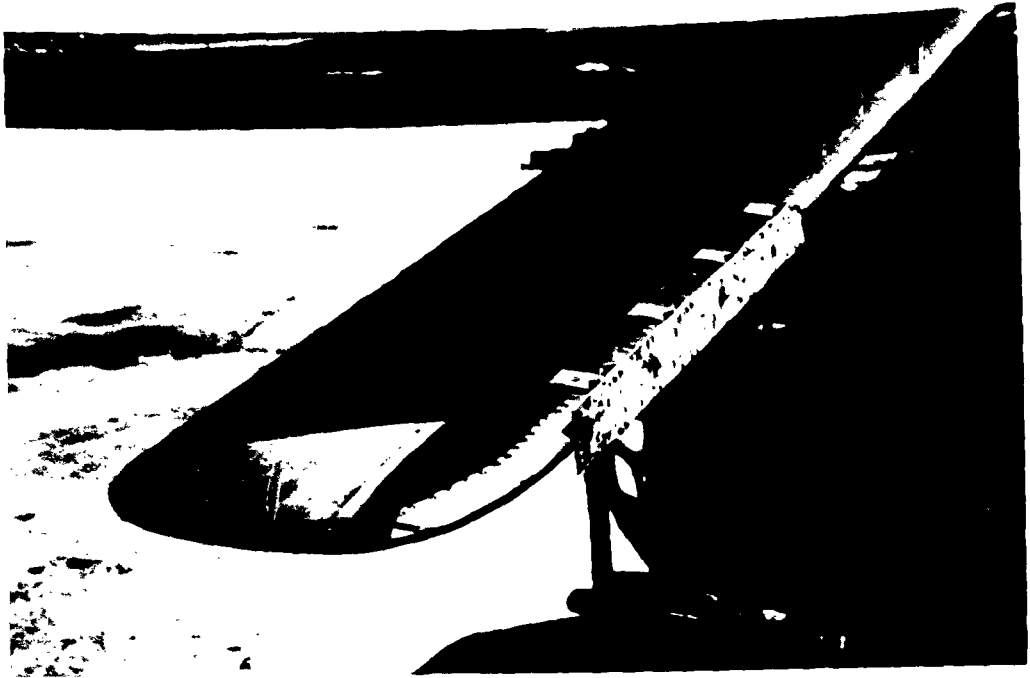


FIG. 4. THE EFFECT OF RUDDER DISPLACEMENT ON ENGINE SPEED.



Drag plate attached to Blade

2" trimmed from inboard end.



Lift spoiler fitted to underside of blade.

PHOTOGRAPHS of BLADE ATTACHMENTS.

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